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BASE-LEVEL OF EOLIAN EROSION

CHARLES R. KEYES

The recognition of a land-level coinciding very nearly with that of the surface of the sea, but below which stream-corrasion cannot go, is a concept which has had such a potent influence in molding opinion concerning land-sculpturing and its evolution that any exception or modification is yet to receive general approval. That the generalization is not of universal application recent observations afford many proofs. Notwithstanding the fact that Powell's Law of the Base-Level of Erosion[1] had its inception in the arid land, later considerations show that it is really strictly referable only to countries enjoying climatic conditions of normal humidity.

Vast areas of the globe there are where, it must be conceded, the effects of stream-corrasion are necessarily very impotent or practically nil. These are the great arid tracts, or deserts, where the annual rainfall is less than ten inches, nearly all of which sinks into a porous and thirsty soil and never appears in the rôle of stream-water. In such regions, as it has been recently shown,[2] erosion and shaping of the land forms are chiefly accomplished by wind-scour, or deflation. The great vigor with which general eolian erosion may operate, when moisture does not interfere, is indicated by the recent estimates that on the soft rock-belts eolative effects are ten times greater than they would be on the same rocks in a humid land, although on the harder rock-masses the rate is scarcely one-tenth so much.

In the general leveling and lowering of the surface of a country notably elevated and fully exposed to the influences of an arid climate, one of the most remarkable results is that the plain is the characteristic and dominant feature from the very beginning of a geographic cycle; while in a humid climate the plain only becomes notably developed in the very last stage.[3] Eolian erosion in a dry country may thus be regarded as pre-eminently plains-forming. On this account, manifestly, it is that in the arid regions of our western country there is the vast general plains-surface, a veritable and illimitable sea of earth out of which, isle-like, rise the myriads of lofty desert ranges whose foundations are the harder rock-masses.

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[1] *Expl. Colorado River of the West* (1875), p. 207.

[2] *Bull. Geol. Soc. America,* XIX (1908), 81; also, *Journal of Geology,* XVII (1909), 31.

[3] *Journal of Geography,* VII (1908), 33.

In the absence of distinctive stream-action in the desert regions there has appeared no delimiting factor controlling the general lowering of an arid area, comparable to that establishing a base-level of erosion postulated for every humid land. The difficulties arising from this want of a general planation-surface to which all relief features of the desert could be referred are especially noted by Passarge[1] in his masterly treatment of the South African "Inselberglandschaft." Penck[2] also appreciates the same difficulty when he suggests that so long as the ocean be held back from a desert eolian erosion might go on indefinitely below sea-level. In his discussion of the geographic cycle in an arid climate Davis[3] apparently recognizes the force of this desideratum, but refers this most conspicuous plains-characteristic to the results of perfected drainage and general lowering, much as they are accomplished under conditions of humid climate, though at an infinitely slower rate. That there is really a level below which eolian erosion in arid regions cannot go and which for all practical purposes corresponds to the base-level of stream-corrasion in a moist country, seems amply demonstrated by recent observations made in Death Valley and in the Imperial Valley, in California, areas lying below sea-level. The testimony seems fully corroborated in other desert valleys of the region.

Until lately the origin of the larger and most characteristic relief-features of the great desert regions of the globe has remained without adequate or satisfactory explanation. Direct genesis upon the basis of ordinary tectonics, or of normal erosion during former wet-climate periods, or of water-action under present conditions, has always met with unsurmountable obstacles. When recently[4] the physiognomy of our western country was briefly considered from the viewpoint of purely eolative origin, the present lofty mountains and the immeasurable intermont plains were regarded simple, differential effects of wind-scour. Extended observations seem conclusively to show that there once existed at a level of about 5,000 feet above the present general plains-surface an old uplifted peneplain. Out of this were sculptured existing highland and lowland, the belts of more resistant rock-masses forming the mountain ranges and the belts of weak rocks the intermont plains. Compared with the usual operations of the geologic processes under normal moist conditions the most noteworthy effects of those under conditions of an arid climate are the prevalency, constancy, and high efficiency of wind-scour action, deflation, or eolation, the very subordinate, local, and sporadic character of water-action, and the remarkable plains-forming tendency which eolian erosion imparts to the landscape.[1]

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[1] *Zeitsch. d. deut. geol. Gesellsch.*, LVI. Bd. (1904), Protokol, p. 191.

[2] *Am. Jour. Sci.* (4), XIX (1905), 165.

[3] *Journal of Geology*, XIII (1905), 382.

[4] *Ibid.*, XVI (1908), 434.

In the South African deserts Passarge has devoted special attention to the work of the winds. The importance of his great generalization lies in the suggestion that it is possible under conditions of an arid climate for the general planation of vast areas to go on without regard to sea-level. For a long time this author[2] found great difficulty in accounting for the great plains-surfaces by wind action alone, for the reason, as he explains, that the wind has no base-level of erosion and must continue the work of excavation and removal wherever the rock-floor is not resistant. There appears to be, however, a limit even to this desert-leveling and eolian excavation. The ground-water level in a structurally inclosed basin must finally put a stop to wind-action by keeping the surface moist, either giving rise to salinas or forming a basin into which sporadic storm-waters find a long resting-place.[3] This would seem to be the case of the Death and Imperial valleys of California, the basin of Lake Eyre in Australia, the Aral and other basins of western Asia, and many of the great depressions of the Sahara.[4]

The absolute independence of one another of neighboring intermont plains, such as everywhere occur in the American arid regions, is perfectly inexplicable on any postulation of normal stream-action. It is, moreover, nowhere more strikingly shown than in the Death Valley district; and it is clearly recognizable throughout the desert country. Nor is this genetic independence of development satisfactorily explained on the basis of tectonics. The profile below, through the Death Valley region, displays these relationships of several adjoining intermont plains.

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[1] *Pop. Sci. Mon.*, LXXIV (1909), 23.

[2] *Zeitsch. d. deut. geol. Gesellsch.*, LVI. Bd. (1905), Protokol, p. 108.

[3] *Am. Jour. Sci.* (4), XVI (1903), 377.

[4] *Bull. Geol. Soc. America*, XIX (1908), 91.

In neighboring valleys of the dry region the local level below which eolian erosion cannot go seems to be sharply determined by lines where the ground-water surface reaches sky. It is much the same as when in a humid land a barrier to surface drainage fixes for a time the local base-level. Those local geologic structures which control ground-water level may be slightly or very different in neighboring intermont areas; but so long as in the one the level of phreatic waters comes to the surface of the ground and in another it does not, the effects of differential deflation will be very marked and plains of the first-mentioned class will remain high above the other, notwithstanding the fact that the two appear to be directly connected so far as their surface drainages are concerned.

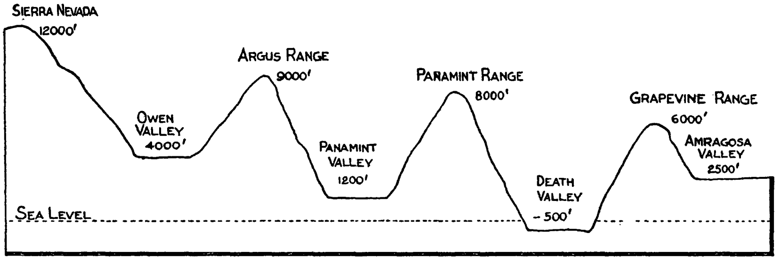

FIG. 1.—Hypsometric Independence of Intermont Valleys of the Arid Region

Death Valley and the Imperial Valley, before the Salton Sea grew so large through the incursion of the waters of the Colorado River, are good illustrations of this phenomenon. In the case of the first-mentioned of these valleys especially, now about 500 feet below sea-level, it is not at all likely that the salt lake which occupies a portion of its area is so much due to the desiccation of surface waters drained into the depression from all sides as it is to the fact that the valley is excavated by deflation down to a level where it could go no farther on account of the inflow of phreatic waters. This seems to be also the true explanation of the presence of many of the salinas and playas which are of such frequent occurrence throughout the arid country. The surface waters derived from the violent but sporadic "cloud-bursts" contribute to playa-formation[1] in many cases, but in the majority of instances the ground-waters doubtless have very much the greater influence.

A noteworthy instance is the Sandoval bolson, or Estancia plains, in central New Mexico. This is the highest and driest bolson of the Mexican tableland within the limits of the United States.[2] Its surface is 6,000 feet above the sea. Its center is occupied by a great chain of dry and bitter lakes. In all of its vast area, and during a period of 400 years since the earliest Spanish invasion, only two small springs of potable water were known within its confines. Recently, it was inferred from the general character of the great basin, its geologic structure, and the location of two springs, that ground-water level at certain points must come very near the surface. Proceeding upon this hypothesis several test-wells were put down and the inference found to be correct. At once there was excavated an area of several acres in extent for reservoir purposes. Now there stands a fine large body of soft water, the surface of which comes within a few feet of that of the surrounding plain. Around the lakelet a prosperous town has sprung up.

As the geographic cycle in an arid region goes on and the whole face of the country becomes worn down to the condition of a peneplain there finally must come a time when the general ground-water level nearly coincides with that of the plains-surface and deflation can proceed no farther. This level which is perfectly independent of sea-level can never be very far below it. The base-leveled area in an arid region may thus compare favorably in size and character with any of the peneplains in humid climates. The base-level of eolian erosion under conditions of an arid climate seems as completely controlled and as sharply delimited by definite physical factors as is normal peneplanation.

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[1] *Am. Jour. Sci.* (4), XVI (1903), 377.

[2] *Journal of Geology*, XVI (1908), 434.